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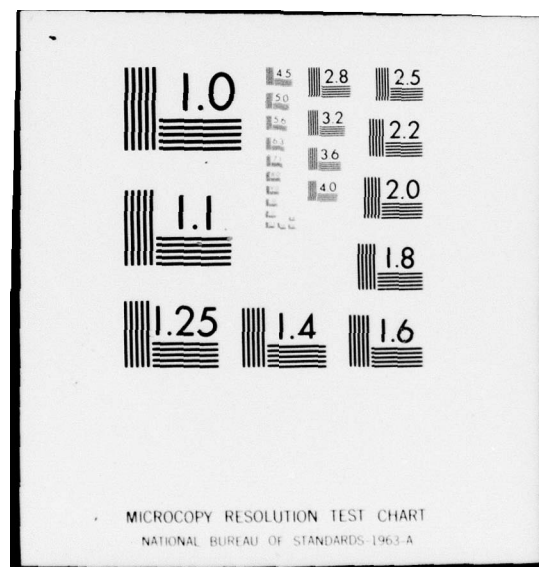
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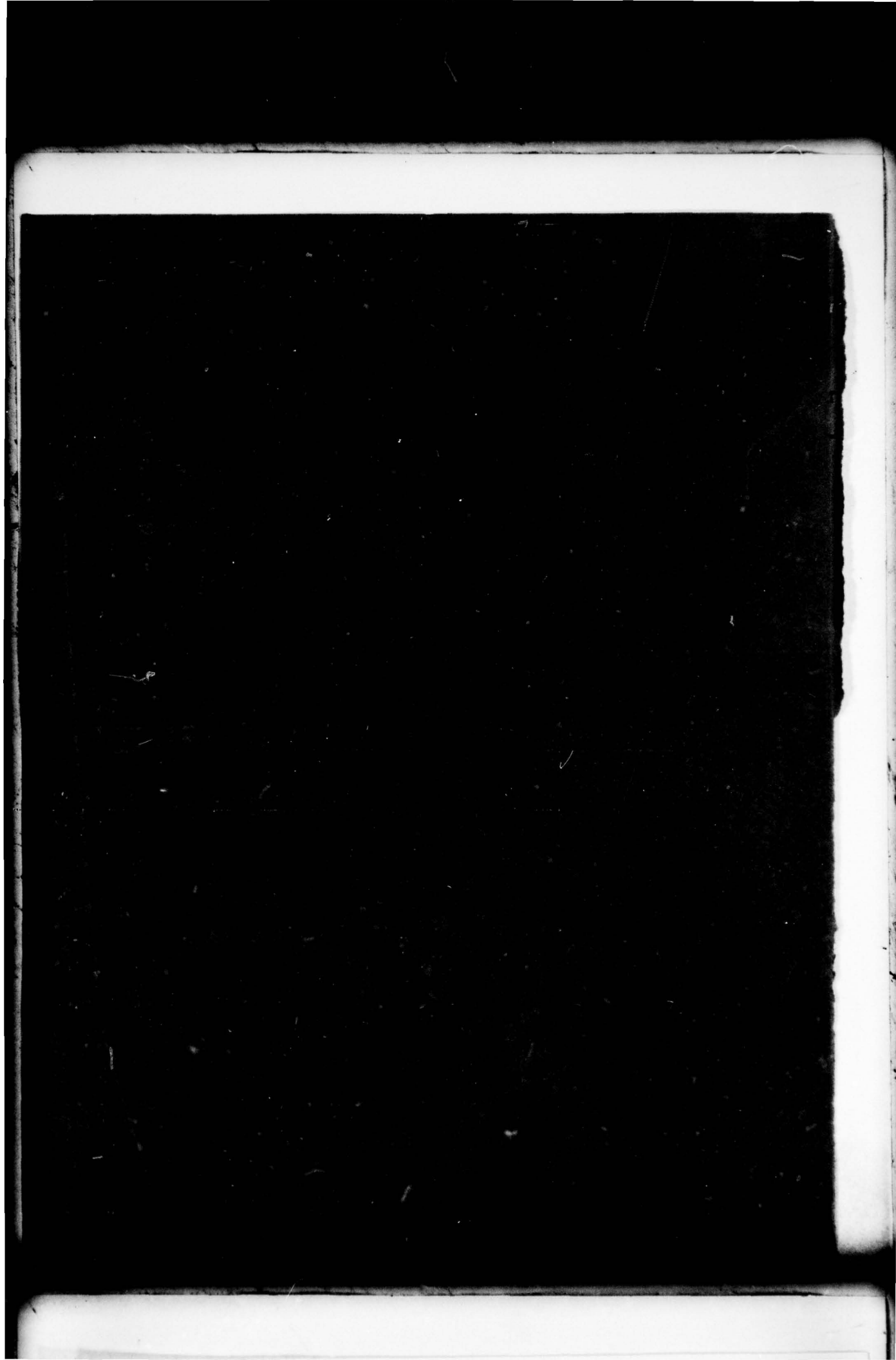




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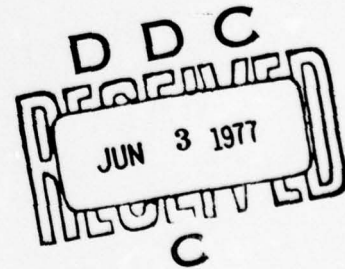
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LINCOLN LABORATORY

ADVANCED ELECTRONIC TECHNOLOGY

QUARTERLY TECHNICAL SUMMARY REPORT
TO THE
AIR FORCE SYSTEMS COMMAND

1 NOVEMBER 1976 - 31 JANUARY 1977

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INTRODUCTION

This Quarterly Technical Summary covers the period 1 November 1976 through 31 January 1977. It consolidates the reports of Division 2 (Data Systems) and Division 8 (Solid State) on the Advanced Electronic Technology Program.

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DATA SYSTEMS
DIVISION 2

INTRODUCTION

This section of the report reviews progress during the period 1 November 1976 through 31 January 1977 on Data Systems. Separate reports describing other work of Division 2 are issued for the following programs:

Seismic Discrimination	ARPA/NMRO
Distributed Surveillance Networks	ARPA/IPTO
Education Technology	Bureau of Mines, ARPA/HRRO
Network Speech Processing	OSD-DCA
Digital Voice Processing	AF/ESD
Packet Speech	ARPA/IPTO
Communications Adaptive Internetting	ARPA/IPTO
Radar Signal Processing Technology	ARMY/BMDATC

M. A. Herlin
Head, Division 2
A. J. McLaughlin
Associate Head

DIGITAL COMPUTERS GROUP 23

I. INTRODUCTION

The fabrication of a set of custom ECL gate array circuits for a speech synthesizer was completed and the synthesizer is operating. A 30×30 MNOS memory array has been operated with offchip decoding circuits. Progress was made on development of the poly-ox dielectric isolation process.

II. APPLICATIONS

A. Gate Array Custom Circuits

The Lincoln Integrated Speech Synthesizer (LISSYN), a real-time speech-processing computer constructed largely of ECL gate arrays, has been completed. It successfully implements the synthesis portion of a linear predictive vocoder in 43 percent of real time. The central processor of the LISSYN consists of eleven gate arrays of five types: four 4-bit ALU slices, four 4-bit slices of other internal registers, one each of two arrays of control circuitry, and one timing phase generator. The average delay per gate is about 1.5 nsec, and the design goal of a 50-nsec cycle time was achieved. Hardware prototyping of each chip and software synthesis of the entire system prevented any need for revision of the logical design of any gate array after its first version was fabricated. Of the twenty packaged gate arrays that have been tried in the LISSYN, only one has been faulty.

The input thresholds and output levels of the gate array differ from nominal ECL 10K levels, so noise margins are small when the arrays interface to ECL 10K circuits. Design changes are being made to the array I/O circuits.

B. Serial-to-Parallel Converter

Masks have been designed and fabricated for the 8-bit Serial/Parallel converter with output holding register which will be made using the poly-ox process. There are two 0.125×0.125 -in. chips - one containing the S/P converter, the other containing a poly-ox evaluation circuit plus a simple logic circuit. Wafers are now being processed using these masks. A 24-pin square leadless package and socket have been chosen for packaging the S/P converter chips.

In order to test these circuits at the design goal of a 1.0-GHz input rate, special circuitry is being built. High-speed discrete-component pulse squarers and gates are being debugged, and a test pattern generator has been designed.

C. MNOS Capacitor Memory Arrays

An offchip diode-resistor partial-decoding circuit fabricated from discrete components has been used to successfully accomplish storage and readout in a 30×30 MNOS capacitor array with 0.2-mil lines on 0.4-mil centers. It is possible to do experiments by contacting the array with a probe card on which is mounted the decoding circuitry. The partial-decoding circuit requires only two diodes and one resistor for each row and for each column of the memory array. The simplicity of this circuit should make it compatible with the densities and fabrication sequence used to form the storage array. The present experimental circuit accomplishes line

selection with mechanical switches. Electronic switching requires devices with 60-V breakdown voltages and substantial current capability. A one-million-bit array will be simulated by a chip with 256 active devices formed by 0.2×0.2 -mil intersections and 768 larger dummied devices. Fabrication of the first wafer with this array is nearly complete.

III. INTEGRATED CIRCUIT PROCESSING

A. Photolithography and Plasma Etching

Photolithographic processing of the poly-ox serial-to-parallel converter and the simulated one-million-bit MNOS array has not presented any problems.

Experimental plasma etching of aluminum has been sufficiently successful to warrant construction of a reactor designed specifically for metal etching. A second reactor is under construction to permit oxide, nitride, and silicon etching with improved uniformity.

B. Self-Aligned Transistors

Two major problems experienced in the fabrication of ion-implanted transistors have been corrected. The poor arsenic-metal contact has been avoided by increasing the arsenic implant dose and decreasing the implant energy, both changes contributing to a higher arsenic doping at the surface of the silicon. The emitter-base leakage has been eliminated by reverting to the practice of annealing each implant separately. The separate anneals also decrease the occurrence of emitter-collector leakage by eliminating the possibility of arsenic-emitter enhanced diffusion through the ion-implanted-damaged regions of the base. The presence of oxygen during the implant anneals has been shown to cause a drastic reduction in beta for a given base doping. Without oxygen, good control over betas has been achieved up to values of 200 to 300. Betas up to 1000 have been observed, but with a rather wide scatter.

C. Poly-Ox Dielectric Isolation

ECL gate chains have been fabricated with the poly-ox dielectric isolation process with acceptable yields. They have a power-delay product one-half that of junction isolated circuits of similar geometry. Work on this particular circuit has concluded, with efforts now directed at the new evaluation circuit designed specifically for the poly-ox process and the serial-to-parallel converter. One problem which has arisen is poor isolation due to apparent inversion of the starting substrate under the spoiler oxide. Experiments using a nitride spoiler layer appear promising.

D. Ion Implanter

The 200-keV ion implanter has become available for routine and special work for Group 23 and other laboratory projects.

IV. DESIGN, ANALYSIS, AND TESTING

A. CV Tests

Capacitance-voltage measurements obtained with the TIC terminal have been used to obtain impurity concentrations for implanted wafers. The same program has been modified to provide MOS data including oxide thickness, flat band voltage, and impurity concentration.

B. Mask Analysis

A mask analysis program, MAP,* is being modified for operation on the IBM 370/168. Mask files will be transferred from the Calma design system to the 370 for artwork design rule verification and other tests.

*C. L. Mitchell, "Mask Analysis Program (MAP) Reference Manual," M&S Computing, Inc., NASA Contractor Report NASA CR-144042, Marshall Space Flight Center (23 June 1976).

COMPUTER SYSTEMS
GROUP 28

On-line data acquisition over a very long land line and communications satellite link was successfully demonstrated during this quarter. An ordinary unconditioned voice grade line was used to transmit data at a 2400-baud rate using binary synchronous protocol. As expected, noise on the line introduced some errors. However, that problem was less significant than apparent errors caused by failure of the sending station to receive positive acknowledgments. Each of these false errors required retransmission of the block just as though it were a real error, and in some cases was sufficiently confusing to abort the entire message sequence. A new experiment is being planned for a conditioned line and 9600-baud rate. Modifications in the transmission protocol will also be made in an effort to determine the cause of the lost acknowledgments.

Two facilities are being developed to further ease user access across the VM time-sharing and VS batch-processing systems. The first facility employs the VM MAIL mechanism to transfer listings from VSBATCH directly to an individual user account. Initially, only listings generated because of job control language errors will be automatically transferred. This will provide a convenient and timely notice of a needed correction. The second facility bridging the systems is a production version of VM/CMS file support for VS. Any allowable VS basic sequential read or write access command may operate directly on a CMS file. This simplifies the development and use of programs across the two systems and eliminates the problem of maintaining duplicate files in different formats.

Several small hardware features were added to the system during this quarter. The number of communications ports was increased by 20 to a total of 160. A new 2400-baud clock has successfully undergone a preliminary test with a Tektronix display terminal connected through Lincoln's standard long hardwire configuration and no external modem. A printing feature has been added to the on-line card punches to eliminate the extra burdensome step of an interpreting run on off-line equipment.

SOLID STATE
DIVISION 8

INTRODUCTION

This section of the report summarizes progress during the period 1 November 1976 through 31 January 1977. The Solid State Research Report for the same period describes the work of Division 8 in more detail. Funding is primarily provided by the Air Force, with additional support provided by the Army, ARPA, NSF, and ERDA.

A. L. McWhorter
Head, Division 8

L. Melngailis
Associate Head

DIVISION 8 REPORTS
ON ADVANCED ELECTRONIC TECHNOLOGY

15 November 1976 through 15 February 1977

PUBLISHED REPORTS

Journal Articles

JA No.

4591	Doppler-Limited and Atmospheric Spectra of the 4- μm $\nu_1 + \nu_3$ Combination Band of SO_2	A. S. Pine P. F. Moulton	J. Mol. Spectrosc. <u>64</u> , 15 (1977)
4611	Laser-Induced Surface Damage of Infrared Nonlinear Materials	H. Kildal G. W. Iseler	Appl. Opt. <u>15</u> , 3062 (1976)
4637	Phenomenological Theory of Raman Scattering in Europium Chalcogenides	S. A. Safran* B. Lax* G. Dresselhaus	Solid State Commun. <u>19</u> , 1217 (1976)
4651	Fluorescence and Dissociative Energy Transfer in High Pressure Ar-HCN Mixtures Excited by Relativistic Electrons	E. Zamir* A. Szöke* R. Osgood	J. Chem. Phys. <u>65</u> , 4885 (1976)
4661	Relaxation Oscillations in Distributed Feedback Lasers	S. R. Chinn	Opt. Commun. <u>19</u> , 208 (1976)
4663	Optical Phonons in AgGaSe_2	A. Miller* G. D. Holah* W. D. Dunnett* G. W. Iseler	Phys. Status Solidi B <u>78</u> , 569 (1976)
4681	Preparation and Properties of PbS Crystals with Low Carrier Concentrations	T. C. Harman A. J. Strauss	J. Electron. Mater. <u>5</u> , 621 (1976)

Meeting Speeches

MS No.

3986	Planar HgCdTe Quadrantal Heterodyne Arrays with GHz Response at 10.6 μm	D. L. Spears	Infrared Phys. <u>17</u> , 5 (1977)
4045A	Electron Energy Loss Spectroscopy of Surface States on Titanium and Vanadium Oxides	V. F. Henrich H. J. Zeiger G. Dresselhaus	Proc. Workshop on Electrocatalysis of Non-Metallic Surfaces, Bethesda, Maryland, 9-12 December 1975, p. 133

* Author not at Lincoln Laboratory.

MS No.

- | | | | |
|-------|---|---|--|
| 4067G | Scalable Tunable IR Lasers | A. Mooradian | In <u>Tunable Lasers and Applications</u> , edited by A. Mooradian, T. Jaeger, and P. Stokseth (Springer-Verlag, Berlin, 1976), p. 60 |
| 4140 | Photoelectrolysis of Water | J. G. Mavroides
D. I. Tchernev
J. A. Kafalas
D. F. Kolesar | Proc. Workshop on Electrocatalysis of Non-Metallic Surfaces, Bethesda, Maryland, 9-12 December 1975, p. 221 |
| 4143 | Stark Model of the Excitonic Surface States Observed on MgO | H. J. Zeiger
V. E. Henrich
G. Dresselhaus | Proc. Workshop on Electrocatalysis of Non-Metallic Surfaces, Bethesda, Maryland, 9-12 December 1975, p. 59 |
| 4174A | Optically Pumped Gas Lasers | H. Kildal
T. F. Deutsch | In <u>Tunable Lasers and Applications</u> , edited by A. Mooradian, T. Jaeger, and P. Stokseth (Springer-Verlag, Berlin, 1976), p. 367 |
| 4319 | Convolvers for DPSK Demodulation of Spread Spectrum Signals | S. A. Reible
J. H. Cafarella
R. W. Ralston
E. Stern | In <u>1976 Ultrasonics Symposium Proceedings</u> (IEEE, New York, 1976), p. 451 |
| 4320 | A Continuously Variable Delay-Line System | V. S. Dolat
R. C. Williamson | In <u>1976 Ultrasonics Symposium Proceedings</u> (IEEE, New York, 1976), p. 419 |
| 4332 | Lincoln Laboratory Program on Thin-Film Photovoltaics | H. J. Zeiger | Proc. ERDA Solar Photovoltaic Program Review Meeting, University of Maine, Orono, 3-5 August 1976, p. 908 |

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UNPUBLISHED REPORTS

Journal ArticlesJA No.

- | | | | |
|------|---|--|---------------------------------------|
| 4622 | Infrared Third-Harmonic Generation in Phasematched CO Gas | H. Kildal | Accepted by IEEE J. Quantum Electron. |
| 4629 | Graphite Intercalation Compounds: Electronic Properties in the Dilute Limit | M. S. Dresselhaus*
G. Dresselhaus
J. E. Fischer* | Accepted by Phys. Rev. B |
| 4666 | Temperature-Gradient LPE Growth of $Pb_{1-x}Sn_xTe$ | S. H. Groves | Accepted by J. Electron. Mater. |

* Author not at Lincoln Laboratory.

JA No.

4677	Submillimeter Heterodyne Detection with Planar GaAs Schottky Barrier Diodes	R. A. Murphy C. O. Bozler C. D. Parker H. R. Fetterman P. E. Tannenwald B. J. Clifton J. P. Donnelly W. T. Lindley	Accepted by IEEE Trans. Microwave Theory Tech.
4684	Microscopic Theory of the Lattice Dynamics of HCP Rare-Earth Metals	J. C. Upadhyaya* A. O. E. Animalu	Accepted by Phys. Rev. B
4693	Resonant Infrared Third-Harmonic Generation in Cryogenic Liquids	H. Kildal S. R. J. Brueck	Accepted by Phys. Rev. Lett.
4700	Low-Dose n-Type Ion Implantation into Cr-Doped GaAs Substrates	J. P. Donnelly C. O. Bozler W. T. Lindley	Accepted by Solid-State Electron.
4703	1500-Hour Continuous CW Operation of Double-Heterostructure GaInAsP/InP Lasers	C. C. Shen J. J. Hsieh T. A. Lind	Accepted by Appl. Phys. Lett.
4708	Schottky Barrier Diodes for Submillimeter Heterodyne Detection	B. J. Clifton	Accepted by IEEE Trans. Microwave Theory Tech.
MS-4230A	$\text{In}_x\text{Ga}_{1-x}\text{As}_y\text{P}_{1-y}/\text{InP}$ Double-Heterostructure Lasers	J. A. Rossi J. J. Hsieh J. P. Donnelly	Accepted for Proc. 1976 North American Symposium on Gallium Arsenide and Related Compounds, St. Louis, 26-29 September 1976
MS-4271	X-Ray Lithography	H. I. Smith D. C. Flanders	Accepted by Jap. J. Appl. Phys.
MS-4302	Ion Implantation in GaAs	J. P. Donnelly	Accepted for Proc. 1976 North American Symposium on Gallium Arsenide and Related Compounds, St. Louis, 26-29 September 1976

Meeting Speeches†MS No.

4140E	Photoelectrolysis of Water	J. G. Mavroides	Boston College Physics Colloquium, Boston, 9 February 1977
4230D	Double-Heterostructure GaInAsP/InP Diode Lasers	J. J. Hsieh	Honeywell Corporate Research Center, Bloomington, Minnesota, 7 December 1976

* Author not at Lincoln Laboratory.

† Titles of Meeting Speeches are listed for information only. No copies are available for distribution.

MS No.			
4309A	High-Temperature Electrolysis and Fuel Cells	T. B. Reed	Energy Seminar, Brookhaven National Laboratory, Upton, New York, 30 November 1976
4335	Schottky Barrier Diodes for Submillimeter Heterodyne Detection	B. J. Clifton	Second International Conference and Winter School on Submillimeter Waves and Their Applications, San Juan, Puerto Rico, 6-10 December 1976
4337	Internal Cavity, Optically Pumped Molecular Laser	H. R. Fetterman H. R. Schlossberg*	
4388	Submillimeter Heterodyne Detection Using Surface-Oriented Schottky Diodes	R. A. Murphy C. O. Bozler C. D. Parker H. R. Fetterman B. J. Clifton J. P. Donnelly W. T. Lindley P. E. Tannenwald	
4343	Second and Fourth Order Nonlinear Processes in Chalcopyrites	H. Kildal G. W. Iseler N. Menyuk J. C. Mikkelsen*	
4358	Semiconductor-Based Infrared Integrated Optics	I. Melngailis	Topical Meeting on Optical Phenomena in Infrared Materials, Annapolis, Maryland, 1-3 December 1976
4344	Molecular-Beam Epitaxy in the Lead-Tin Chalcogenides	J. N. Walpole	Annual Meeting of Materials Research Society, Cambridge, Massachusetts, 15-17 November 1976
4362	Studies of Defect Surface States on SrTiO_3 Photoelectrolytic Electrodes	J. G. Mavroides V. E. Henrich H. J. Zeiger G. Dresselhaus J. A. Kafalas D. F. Kolesar	
4381	Adsorption of O_2 and H_2O by Surface Defects on TiO_2 and SrTiO_3	V. E. Henrich G. Dresselhaus H. J. Zeiger	Workshop on Physical Adsorption, Brookhaven National Laboratory, Upton, New York, 28-30 December 1976

* Author not at Lincoln Laboratory.

SOLID STATE DIVISION 8

I. SOLID STATE DEVICE RESEARCH

By using a commercial PbSnSe diode laser operated in a cryogenic closed-cycle cooler and a state-of-the-art HgCdTe photodiode, high-resolution absorption spectra of ethylene were obtained by heterodyne radiometry. The observed signal-to-noise ratio obtained with the diode laser LO and a blackbody source was only about a factor of 2 less than the best S/N obtained using a CO₂ laser LO. The latter was about 45 percent of the theoretical limit for an ideal heterodyne receiver. The diode laser driven by a moderately regulated power supply was found to have a 100-kHz instantaneous linewidth.

CW operation has been achieved in distributed-feedback PbSnTe stripe-geometry double-heterostructure diode lasers grown by molecular-beam epitaxy. The lasers emit near $\lambda \approx 12.5 \mu\text{m}$ for heat-sink temperatures between 12 and 50 K, and single-mode operation is obtained for large variations in diode current and heat-sink temperature. Also, continuous current-tuning of the mode frequency over a 7-cm^{-1} -wide band is observed.

II. QUANTUM ELECTRONICS

Grating tuning of the output of the HBr-pumped $16\text{-}\mu\text{m}$ CO₂ laser has been accomplished. With the tuned cavity, experiments elucidating the kinetics of this laser medium have been performed. In addition, $1/3 \text{ mJ}$ of energy in a single pulse was obtained.

Studies of the vibrational kinetics of simple liquids have been extended with the investigation of CH₃F and SF₆ kinetics in liquid Ar and O₂ hosts by means of saturation techniques. For CH₃F, a simple saturation behavior with a $150 \pm 50\text{-nsec}$ V-T decay time was found. SF₆ exhibits a more complex behavior due to excited-state absorption processes: rate limiting steps of $54 \pm 15 \text{ psec}$ in liquid O₂, and $320 \pm 80 \text{ psec}$ in liquid Ar were found. The implications of the molecular spectroscopy in the cryogenic liquid environment for the modeling of vibrational energy flow within these molecules have been considered.

Acoustic spectrophone measurements of the absorption of pulsed CO₂ laser radiation by cooled and room-temperature SF₆ have been made in order to study multiphoton absorption processes in polyatomic molecules. The absorption shows a strong dependence on laser frequency, laser energy, and temperature.

III. MATERIALS RESEARCH

A technique has been developed for the fabrication of thin, corrugated, stabilized-zirconia disks that could be used as membranes for oxygen-ion transport in high-temperature electrolysis cells. A slurry of zirconia in an organic solvent is spread on a glass plate to form a rubbery "green sheet," which is then deformed to the desired shape, fired at 1600°C in air, and finally fired at 2200°C in a reducing atmosphere to give a high-density, translucent ceramic.

The role of semiconductor surface states in the photoelectrolysis of water is being investigated by means of *in situ* photoresponse measurements on SrTiO₃ electrodes in photoelectrochemical cells. Photons with below-bandgap energies excite photocurrents with long time constants (of the order of minutes) that are associated with the reduction of O₂ by electrons transferred from the surface states of SrTiO₃ to the conduction band.

Thin films of Sn-doped In_2O_3 , which can be used as heat mirrors for solar collectors and as transparent electrodes for solar cells, have been studied by x-ray photoemission spectroscopy in an attempt to understand the factors determining their electrical and optical properties. The photoemission data suggest that darkening of such films, which seriously reduces their usefulness, is due to formation of an Sn_3O_4 -like second phase.

IV. MICROELECTRONICS

A chip has been designed to add n-channel MOS shift registers and latch circuits to the original prototype CCD programmable transversal filter structure. In the prototype device, the tap weights were programmable as digital words which were controlled by switches external to the chip, but in the final device the digital words are to be stored on the chip in static logic devices. The analog input structure to the CCD sections has also been modified to make it controllable by the positive voltage levels of the logic devices.

Electrical characterization of the first of the 100×400 -cell CCD imaging devices to be fabricated for the GEODSS (Ground Electro-Optical Deep Space Surveillance) program has begun. The time constants and densities of two trap levels thought to be responsible for transfer inefficiency have been identified by using a technique based on sequentially injected electrical signals. The most prominent source of transfer loss is a trap level which appears to be the acceptor level of gold located near the middle of the band gap.

Small, planar, surface-oriented Schottky diodes in which both terminals of the rectifying junction are on the same surface of the GaAs wafer have been fabricated and operated for the first time as detectors at submillimeter wavelengths. The planar configuration lends itself naturally to an integrated circuit approach, enabling the connection of matched strip-line antennas and IF filter networks. Diodes with diameters as small as $2 \mu\text{m}$ have been fabricated and evaluated as harmonic mixers up to 668 GHz.

Quantitative measurements have been made of photoresist linewidth as a function of exposure time and exposure order for the double-reticle technique used to eliminate faults, which arise from particulate contamination or emulsion defects in the 10 X reticle, in chromium-coated master masks. In this technique, the mask is exposed in the step-and-repeat camera with a reticle having nominal-sized geometries and with a second reticle having slightly oversized geometries. These measurements indicate that the exposure time per reticle to achieve a desired linewidth is less for the double-reticle technique than when using a single reticle, and that exposing the oversized reticle first in the double-reticle process results in longer total exposure times for optimum linewidths.

V. SURFACE-WAVE TECHNOLOGY

The program to develop surface-acoustic-wave (SAW) pulse expanders and compressors for the MASR (Multiple-Antenna Surveillance Radar) system has been completed. The devices were fabricated in the reflective-array-compressor (RAC) configuration on bismuth germanium oxide (BGO). Sets of devices were developed to generate and process a narrowband linear-FM waveform (2.5 MHz, 125 μsec) and a wideband waveform (10 MHz, 150 μsec). The low surface-wave velocity on BGO allowed compact devices capable of processing these relatively large dispersions to be fabricated on commercially available 15-cm substrates. Low spurious levels, large dynamic range, large compression ratios, and good sidelobe suppression are characteristic features of these devices. Good control of phase and amplitude response yields peak near-in sidelobes of 35 dB, and the unique RAC geometry suppresses far-out sidelobes by more than 80 dB.

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